Comparison of low-cost hand-monitoring devices for motor rehabilitation

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SUMMARY

Impaired individuation of the fingers is now being recognized as an important impediment to recovery of upper limb function. Computer-based rehabilitation tools can be used to improve hand/finger function while keeping the user engaged and more likely to perform the exercises on a daily basis[1].

We assessed 3 hand kinematic devices and their potential use in a clinical setting for hand rehabilitation:

- Leap Motion IR Camera
- 5-DT 14 Sensor Data Glove
- Vhand DGTech 5 Sensor Data Glove

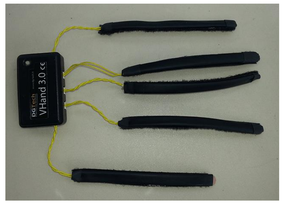
The Leap Motion device was the most accurate and easiest to use for fully functioning subjects but failed to capture hand kinematics of stroke patients due to obstructed view of their partially closed hands.

The 5-DT data glove produced the most reliable performance during computer driven rehabilitation tasks but fails to give accurate real-world joint angles of the subject.

The Vhand DGTech data glove could only detect large finger movements, lacking the sensitivity to be used in fine motor rehabilitation tasks.

5DT Data Glove

VHand DGTech Glove

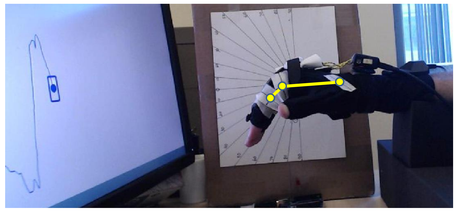


Leap Motion IR Camera

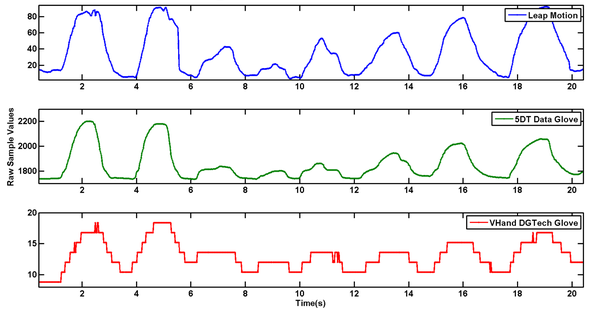
DEVICE CALIBRATION

While being video-taped wearing each device, non-impaired subjects moved their fingers to a variety of finger angles between 0° and 90° under the direction of a MATLAB-based behavioral program that sampled the entire finger movement space.

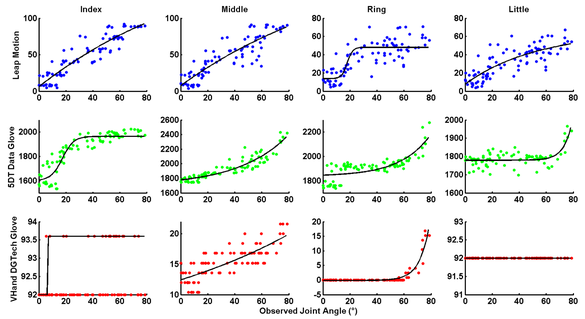
Video recordings from the side of the hand were used to calculate the actual angle of the MCP joint. The true joint angles were then compared the raw values of the devices to estimate a transition function.



Raw Signals of the Devices



Raw Signal Compared to Observed Joint Angle

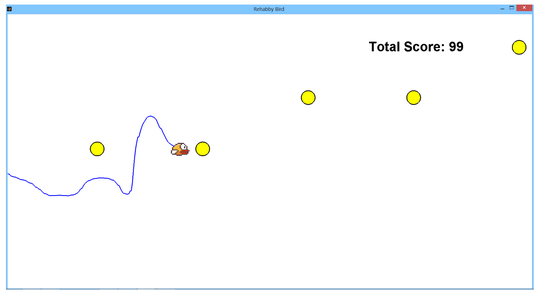


REHABILITATION TASK

To practice controlled finger movements, subjects played a target acquisition game for 1 hour.

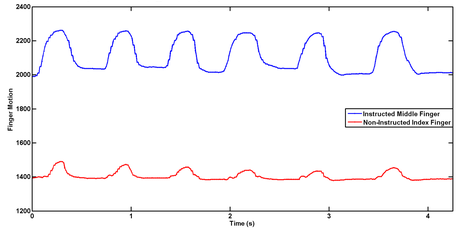
After a brief calibration phase of opening and closing the hand to the best of the subject's ability, gold targets slowly moved across the screen within the subject's movement range.

The subject moved the game cursor in the shape of a flapping bird by moving their index finger up and down without moving their middle finger. As targets were acquired or missed, the difficulty of the game adapted by adjusting a series of game parameters to keep the success rate at 80%.

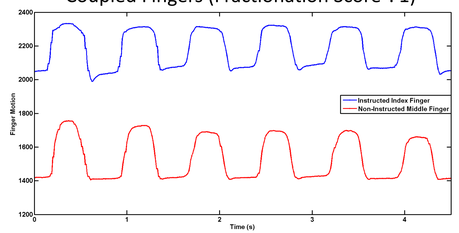


Ability to move the Index and Middle fingers Independently

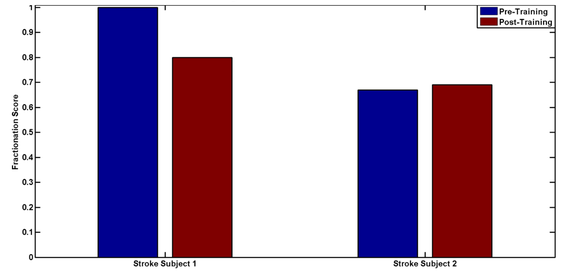
Uncoupled Fingers (Fractionation Score[2] : 0.1)



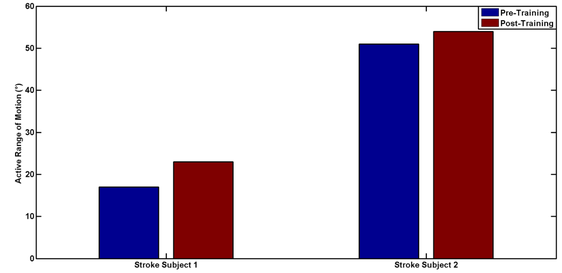
Coupled Fingers (Fractionation Score[2]: 1)



Stroke Subject Fractionation[2]



Range of Motion



CONCLUSION

Device	Leap Motion	5DT Glove	Vhand DGTech Glove
Technology	Dual IR Cameras	Fiber Optic	Piezo-Resistive
Price	$80	$5420 per glove	$800 per glove
# of Joints	>14	14	5
Sensor Precision	32 bit	8 bit	~4 bit
Sample Frequency	up to 115Hz	200Hz	100Hz
Advantages	+ No setup or calibration required + Linear translation of Joint Angle + Extremely low cost + Actively being developed and improved	+ Works with any hand position/orientation + High Resolution and sample rate to detect the slightest movement + Quick glove setup	+ Works with any hand position/orientation + Glove can accommodate any hand size
Disadvantages	- Difficulty measuring a closed hand - Requires a specific hand orientation for optimal results - Limited to fully functioning subjects - Can lose tracking of the hand causing erratic jumps in measurements - Difficulty measuring small hands - Utilizes a large % of the USB card	- High cost - Time consuming calibration method for real-world joint angle measurements - Non-linear calibration makes measurements near the sensor limits highly inaccurate - Requires an additional glove for small hands	- Low sampling resolution cannot capture small movements - Non-linear calibration makes measurements near the sensor limits highly inaccurate - Time consuming setup - Low quality highly variable sensors - Difficult to initialize with computer
Applications	• Non-distonic subjects with near full hand range • Software development	• Subjects with limited hand movement range	• Subjects with small hands • Subjects that have difficulty putting on a glove.

- Due to the stroke patient's limitations in hand position, the 5DT data glove is recommended for rehabilitation use.
- For most other uses, including the development of rehabilitation applications, Leap Motion is the cheapest, fastest to setup, and provides the clearest results.
- Finger fractionation can be improved even from brief amounts of training, especially when the subjects are kept mentally engaged during the training period.

REFERENCES

1. Adamovich SV et al. *A virtual reality based exercise system for hand rehabilitation post-stroke: transfer to function.* 26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, IEMBS 2004, 4936-4939.

2. Lang CE and Schieber MH. *Differential impairment of individuated finger movements in humans after damage to the motor cortex or the corticospinal tract.* J Neurophysiol 90: 1160–1170, 2003.

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